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(19) (CA) **CANADIAN PATENT** (12)

(54) Process for Confining Steam Injected Into a Heavy Oil Reservoir

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"PROCESS FOR CONFINING STEAM INJECTED INTO A HEAVY OIL RESERVOIR"

ABSTRACT OF THE DISCLOSURE

The process is practised in the context of a first pattern of wells completed in a first portion of a heavy oil reservoir. The first pattern has undergone steaming and production and the underlying reservoir portion is significantly depleted. A second pattern of wells is completed in a second less-depleted portion of the reservoir. The two reservoir portions are adjacent and in fluid communication. This may be through a laterally extending thief zone high in the reservoir, the thief zone having higher permeability to steam than the main body of the reservoir. Steam injected into the second portion thus will be lost into the depleted portion. The process comprises injecting non-condensable gas into the depleted portion while steaming and producing oil from the less-depleted second portion. The gas is injected at a rate sufficient to maintain the pressure in the two reservoir portions about equal. As a result, the loss of steam to the depleted portion is inhibited.

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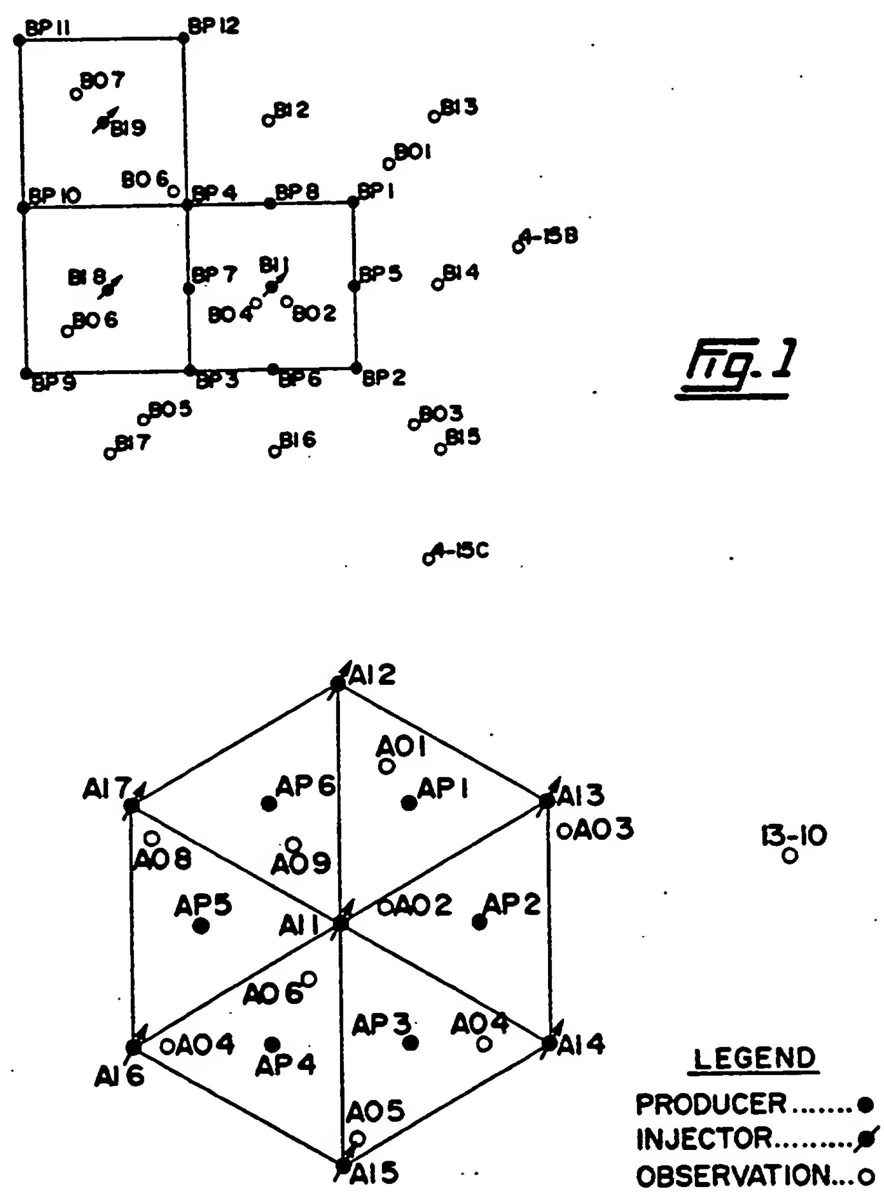

Fig. 1

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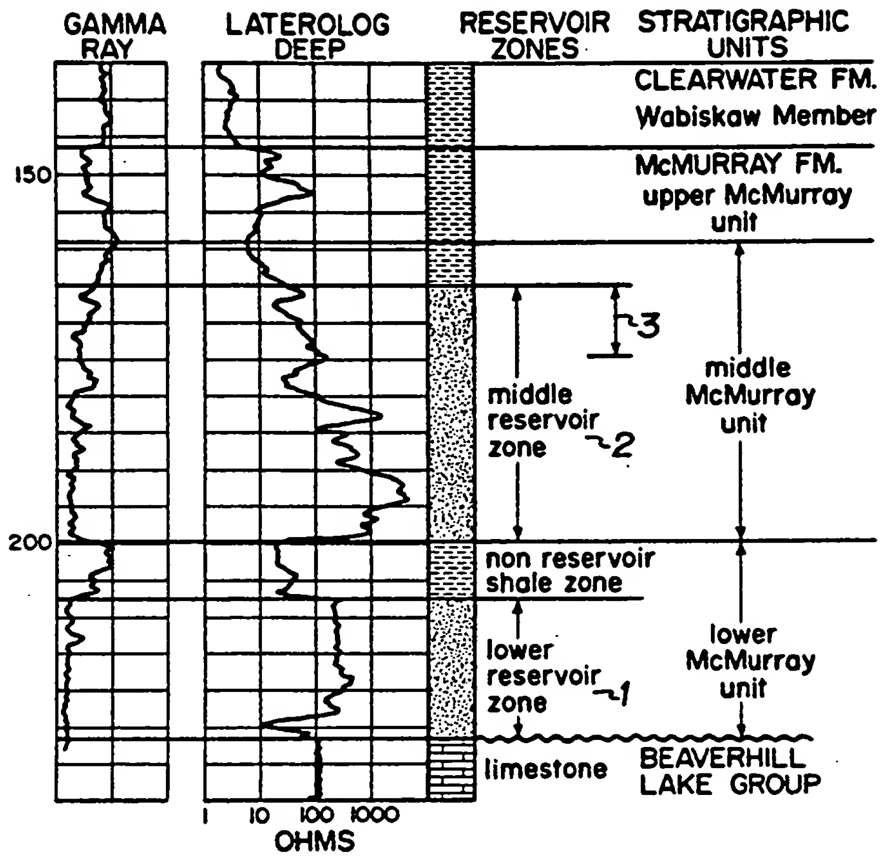

Fig. 2.

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CANTERRA/ESSO/AOSTRA A.T.S. PILOT

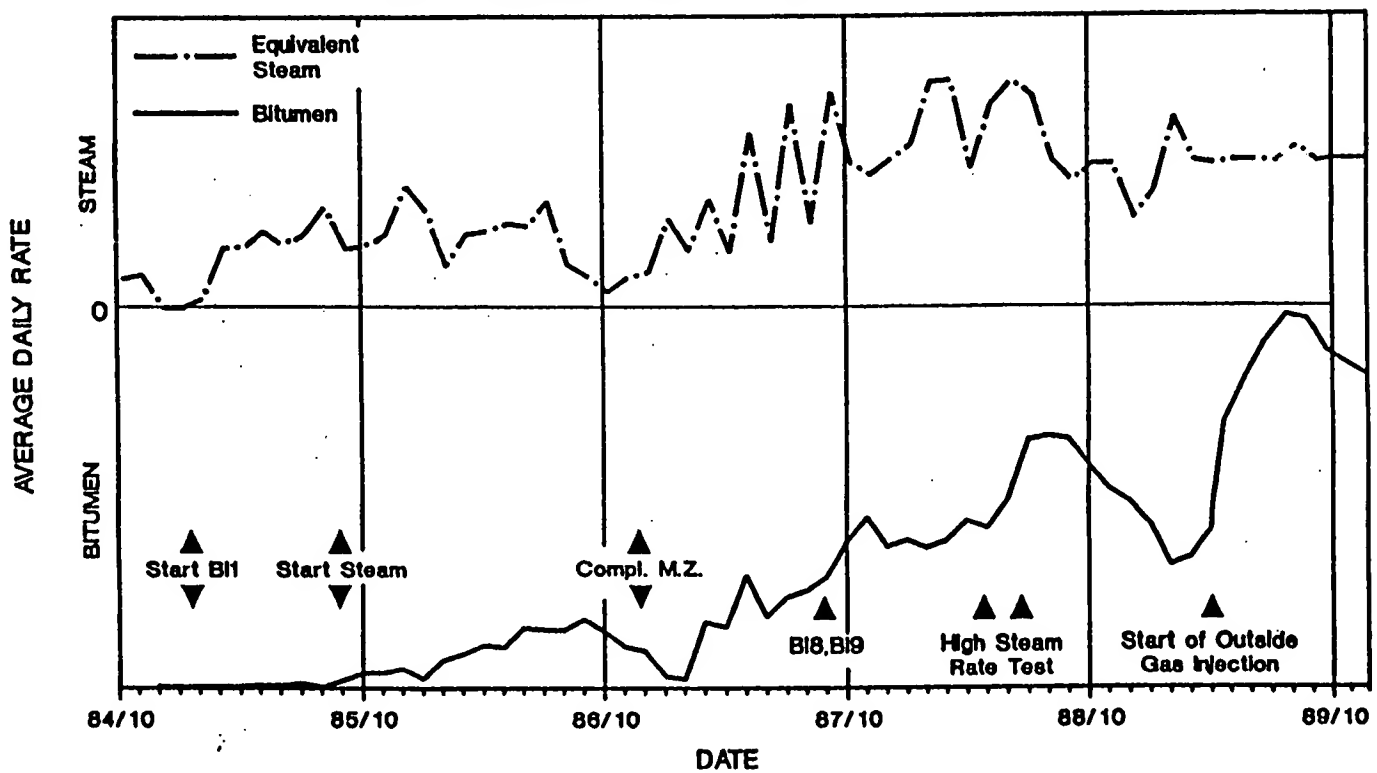

Fig. 3.

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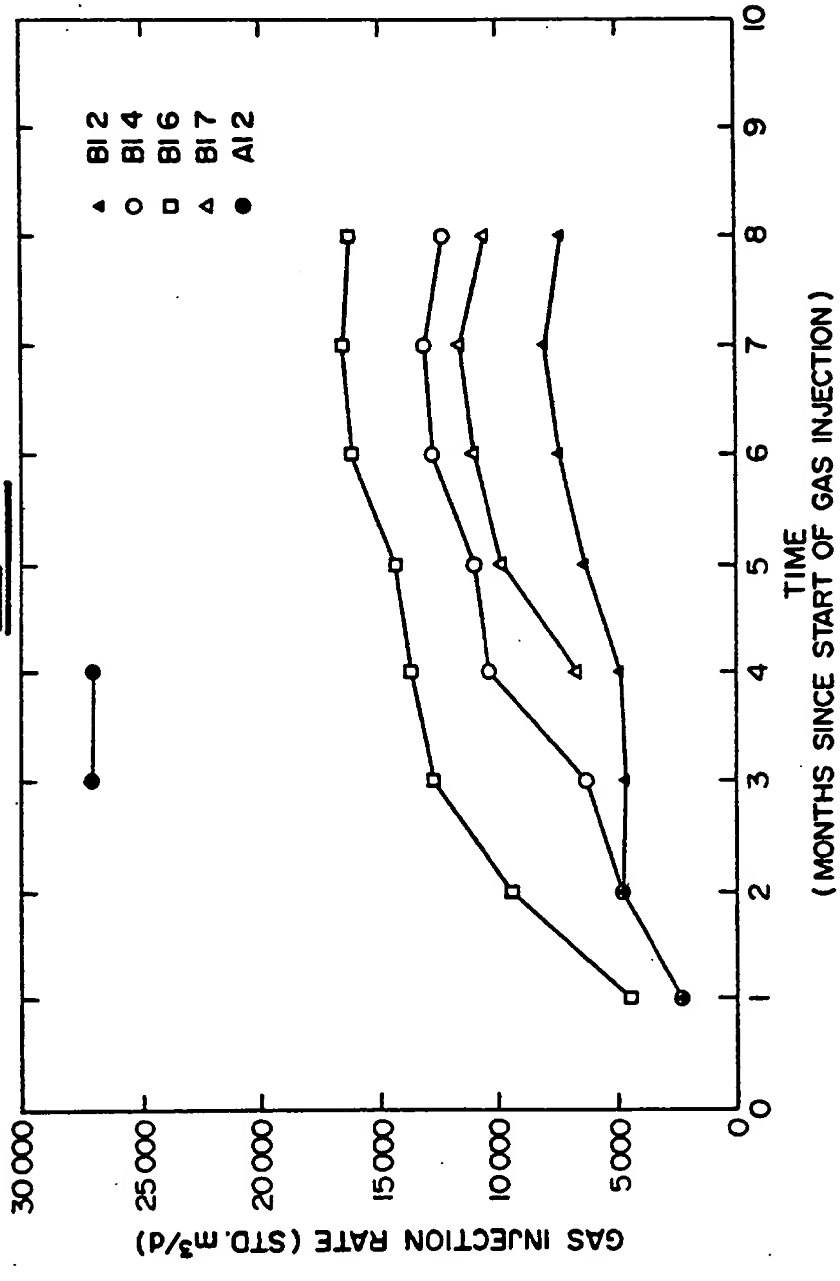
Fig. 4.



Field of the Invention

This invention relates to an improvement of a steam injection process for the recovery of heavy oil. More particularly, it relates to injecting non-condensable gas into a depleted portion of a reservoir to pressure it up and prevent the escape of steam thereinto, which steam is being injected into an adjacent portion of the reservoir.

BACKGROUND OF THE INVENTION

It is conventional practice to inject steam into a heavy oil reservoir to heat the formation and reduce the viscosity of the oil, thereafter producing the oil once its mobility has been improved. Such an operation is commonly referred to as a "thermal project".

A problem can arise with respect to a thermal project if a "thief zone" is in communication with the oil reservoir into which the steam is being injected. If this is the case, the injected steam will preferentially move into the thief zone. Heating of the oil-saturated portion of the reservoir is then reduced.

Frequently the thief zone is a laterally extending section of that portion of the oil-containing reservoir that is to be heated. The section typically will have a relatively high gas or water saturation. Often it is located at the top of or high in the reservoir.

A thief zone can also occur in another manner. In heavy oil thermal projects it is common procedure to practice steam injection and oil production in a first area and, when the reservoir underlying the area is significantly depleted, to then expand the project by commencing operations in an adjacent second area. In some cases, the depleted first portion of the reservoir is in fluid communication with the non-depleted second portion of the reservoir. In this situation, steam injected into the non-depleted portion of the reservoir may migrate into the depleted portion. As a result, the depleted first portion of the reservoir constitutes a thief zone for steam being injected into the second portion.

When steam escapes into such a thief zone, it is found that injection pressure diminishes and the temperature in the producing portion of the reservoir is relatively low. As a result, the oil production rate also drops off.

There is therefore a need for a process that will inhibit losses of injected steam through or into a thief zone.

SUMMARY OF THE INVENTION

This embodiment of the invention is concerned with a situation where there are two adjacent steam injection and fluid production patterns, both completed in the same reservoir. The reservoir portion underlying the first pattern has already experienced some steam injection and oil production. Thus it is

partially depleted. The reservoir portion underlying the second pattern has experienced less depletion. There is fluid communication between the patterns - stated otherwise, steam injected through the wells of the second pattern will enter the more depleted reservoir portion.

In accordance with the invention, non-condensable gas is injected through wells of the first pattern into the more depleted reservoir portion at the same time that steam is injected through wells of the second pattern. Preferably the non-condensable gas is injected at a rate and in an amount sufficient to substantially equalize the pressure in the more depleted reservoir portion with the pressure in the steam zone in the second reservoir portion. When this is done, steam loss into the more depleted portion of the reservoir is inhibited with a concomitant improvement in oil production and steam/oil ratio at the second pattern. The gas injected into the first pattern may also contribute to improved performance in the production wells within the first pattern.

DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic showing the patterns and the gas injection wells which were used in demonstrating the invention at a pilot project;

Figure 2 illustrates with logs the nature of the reservoir in the pilot test area;

Figure 3 is a plot showing steam injection and bitumen production rates for the B pattern of the pilot test. Arrows on the plot indicate when the injection well BI1 was started up, when BI1 injection was switched from hot water to steam, when the middle zone was completed, when injection wells BI8 and BI9 were started up, when the high steam rate test was conducted, and when outside gas injection began; and

Figure 4 is a plot of gas injection rate through the wells identified on the plot.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention is exemplified by the following example based on a pilot test conducted in the Kearl Lake region of Alberta.

The reservoir at the pilot site, depicted in Figure 2, has two oil producing pay zones, a lower zone 1 and a middle zone 2. The middle pay zone 1 is approximately 35 m thick and has a sand region 3 at its upper end. This region 3 is approximately 10 m thick and has significantly higher water saturation than the pay zone 2. The region 3 constitutes a thief zone for steam injected through well perforations in the pay zones 1,2.

The bitumen in the pay zone 2 is effectively immobile at initial reservoir conditions.

A steam drive pilot was initiated in an A pattern consisting of steam injection wells and production wells. The layout of the A pattern wells is shown in Figure 1. Each well

is identified as to pattern (A), nature (injection (I), production (P), or observation (O)) and number. The A pattern was an inverted 7-spot with peripheral steam injection to enclose the pattern and make it equivalent to an inner pattern in a commercial project. The pattern covered 5.37 acres.

At the same time that the A pattern was drilled, an adjacent B pattern was also drilled. The B pattern was originally an inverted 5-spot surrounded by 8 steam injection wells. It was decided to delay start-up of the B pattern to gain operating experience on the A pattern.

A steam drive was initiated in December, 1981, in the A pattern and continued for 5 years. Steam was injected into the AI wells and fluid was produced from the AP wells.

It became clear that a large volume of steam was being lost from the A pattern, as the steam-oil ratio was very high.

As a result of the A pattern experience, changes were made to the B pattern prior to its start-up. It was decided not to inject steam into the peripheral wells of the B pattern. Instead the B pattern was converted from a 5-spot to a 9-spot.

Start-up of the BI1 pattern occurred in February, 1985, and start-up of the patterns of BI8 and BI9 was initiated in September, 1987. Steam was injected through the 3 injection wells and fluid produced from the 12 production wells in conventional fashion.

Wells BI2, BI3, BI4, BI5, BI6 and BI7 were also completed in the reservoir as observation wells and were used to monitor temperature and pressure outside the B pattern.

The chronology of operations in the B pattern and the effect on bitumen production is shown in Figure 3. Hot water injection was initiated into the lower zone 1 of the BI1 pattern in February, 1985. Steam injection into the lower zone 1 of the BI1 pattern began in August, 1985. Middle zone 2 operations began in December, 1986. The BI8 and BI9 patterns were added in September, 1987.

A high rate steam test was conducted in the summer of 1988 in which the steam injection rate was approximately doubled for a period of about two months.

The outside gas injection test was begun in April, 1989, with the injection of natural gas into wells BI2, BI4 and BI6 following perforation of those wells in the region 3 of the middle zone 2. Gas injection into wells BI7 and AI2 was initiated a few months later, as shown in Figure 4.

As shown in Figure 3, the high rate steam test resulted in a significant increase in bitumen production rates, but the steam-oil ratio did not improve.

After the high rate steam test, the bitumen production rate fell considerably until March, 1989, when the steam stimulation of some production wells began in anticipation of the outside gas injection test.

As stated, the outside gas injection test began in April 1989, and is still continuing. Gas injection was conducted simultaneously with steam injection. More particularly, during the outside gas injection test, the steam injection rate was held constant at a rate of only about 60% of that during the high rate steam test. The bitumen production rate during the outside gas injection test

started to increase significantly within one month, and, over the eight month period since gas injection began, the bitumen production rate has, on average, been more than 80% higher than that prior to gas injection.

The instantaneous steam-oil ratio during the outside gas injection test also improved considerably over that observed prior to outside gas injection.

No detrimental effects of outside gas injection have been observed. There has been no noticeable increase in gas production at the production wells. The injected gas remains near the top of the payzone 2 due to gravity effects, while liquids are produced through perforated intervals near the base of the pay zone.

Prior to outside gas injection, the region 3 allowed fluids to flow out of the B Pattern. In particular, steam, hot water and hot bitumen flowed out of the B pattern during steam injection within the pattern. This was evidenced by temperature and pressure measurements at the observation wells outside the pattern and by the fact that the pressure within the pattern remained low. When the steam injection rate was increased in the B pattern, a temperature response could be detected even within the A pattern. Thus the A pattern constituted a thief zone in communication with the B pattern.

At the time gas injection began into region 3 through wells outside the B pattern, the pressure within the B pattern was only about 800 kPa. The native reservoir pressure is about

300 kPa. Within three months of the commencement of outside gas injection, the pressure within the B pattern increased from 800 kPa to over 1000 kPa and the pressure within the A pattern increased from about 400 kPa to over 900 kPa. Within the B pattern, the temperature increased along with the pressure as determined by saturated steam conditions within the B pattern.

Prior to and during the outside gas injection operation, wells AP1 and AP3 and AP6 were maintained on production even though no steam was injected into any wells in the A pattern. Prior to the commencement of outside gas injection, the A pattern wells benefitted from heat communication with the B pattern but this heat communication was eliminated when gas injection began. Even though the A pattern wells lost heat communication, the production performance of wells AP1, AP3 and AP6 has increased over that prior to gas injection. This increased production is believed to be related to an improved gravity drainage mechanism due to the increased gas saturation in the A pattern.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method for recovering heavy oil that is effectively immobile at reservoir conditions, from a reservoir having a partially-depleted portion penetrated by a first pattern of wells and an adjacent less-depleted portion penetrated by a second pattern of steam injection and oil production wells which are completed in said less-depleted portion, the less-depleted portion of the reservoir being in fluid communication with the partially-depleted portion, comprising:

injecting steam into the less-depleted portion of the reservoir through the injection wells of the second pattern, to heat the oil in said portion and render it mobile;

simultaneously injecting non-condensable gas, through at least one well of the first pattern, into the partially-depleted portion of the reservoir at a rate and in an amount sufficient to maintain the pressure in the partially-depleted portion at the gas injection wells about equal with the pressure in the reservoir portion underlying the second pattern and undergoing steam injection; and

producing heated oil from the second pattern.

2. The method as set forth in claim 1 wherein:

the non-condensable gas injected is selected from the group consisting of natural gas, flue gas and carbon dioxide.

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3. The method as set forth in claim 2 wherein:

the production wells of the second pattern are perforated low in the payzone of the reservoir.

4. The method as set forth in claim 3 wherein:

the reservoir portions are in fluid communication through a thief zone high in the reservoir.

5. The method as set forth in claim 1 wherein:

the reservoir portions are in fluid communication through a thief zone high in the reservoir; and

steam and gas injection are continued simultaneously after heat breakthrough at the production wells of the second pattern.